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PROGRESS REPORT OF RESIDUE STUDIES ON ORGANIC ARSENICALS USED FOR DITCHBANK WEED CONTROL

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16. ABSTRACT

Monosodium methanearsonate (MSMA) was applied to the ditchbanks of full and dewatered irrigation systems on the Rio Grande Project to control ditchbank weeds and to determine the MSMA residues in irrigation water. Information obtained will provide support for the registration of organic arsenicals used for weed control along full and/or dewatered ditchbanks. Water samples were analyzed for total arsenic content after sulfuric-nitric acid digestion by the silver diethyldithiocarbamate method. Maximum arsenic concentrations found in the first water released through dewatered laterals were 0.54, 0.12, and 0.29 ppm, dropping below the mandatory U.S. Public Health Service Drinking Water Standards for arsenic within 10 minutes. Maximum arsenic concentrations in full systems following MSMA herbicide application to ditchbanks were 0.16, 0.17, and 0.86 ppm, but dropped rapidly after a period of time. Test results show that low levels of arsenic occur in irrigation water for short periods of time following ditchbank applications of MSMA. Theoretical calculations indicate that from 0.002 to 0.04 lb of arsenic per acre per treatment could reach the farmland during a 24-hour period using 6 inches of irrigation water.

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CONTENTS

	Page
Introduction	1
Summary	2
Materials and Methods	2
Herbicide Application	2
Sample Collection	3
Analytical Procedure	4
Results and Discussions	4
Dewatered Irrigation Laterals	4
Full Irrigation Systems	5
Arsenic Residues on Farmland	6
Organic Arsenical Analysis	6
References	7

LIST OF TABLES

Table		
1	Herbicide application data on MSMA treatments made on three dewatered laterals of the Rio Grande Project in 1970	3
2	Herbicide application data on MSMA treatments made on three full irrigation systems of the Rio Grande Project in 1971	3
3	Arsenic concentration found in first released water samples after MSMA application to dewatered laterals	4
4	Arsenic concentration found in water samples after MSMA application to full irrigation systems	5
5	Quantity of arsenic computed from levels of organic arsenicals found in irrigation water that may be distributed to farmland from ditchbank applications of organic arsenicals	6
6	Percent recovery of arsenic from MSMA in water using hot nitric-sulfuric acid digestion	7
7	Effect of sample treatment on MSMA concentration in Rio Grande Project irrigation water during storage	7

INTRODUCTION

The Bureau of Reclamation (USBR) operates and maintains irrigation canals in the Western United States, including California, Texas, Oklahoma, and New Mexico where a severe problem of Johnsongrass infestation occurs. Johnsongrass not only grows along irrigation systems and invades water channels, but it produces extensive infestations along fence rows, around buildings, and competes so successfully in some cropping areas as to become the dominant plant in the field. The USBR has found the organic arsenicals to be the most effective and economical agents for controlling Johnsongrass on ditchbanks.

During the past few years, organic pentavalent forms of arsenic such as monosodium methanearsonate (MSMA) and disodium methanearsonate (DSMA) have been used extensively for the selective control of weeds in crop and noncrop areas(1)*(2)(3)(4). The USBR uses organic arsenicals primarily on ditchbanks, an aquatic environment. However, the use pattern by the USBR is completely different from that of a farmer where the herbicide is applied directly to a field while the crops are growing. The use pattern of the USBR is to apply 2 to 4 pounds (lb) of MSMA per acre of ditchbank, two to four times per year. A trained crew using a mobile, calibrated spray rig applies the herbicide in a water solution to the canal ditchbank. A complete weed control program not only includes herbicide application, but also burning and mowing. Weed control problems and programs of the Rio Grande Project have been reviewed by Kirby and Summers(5).

Schroeder and Balassa(6) conducted a review of the literature on arsenic and its relation to man. They state that arsenic exists in the environment of man in the trivalent and pentavalent forms. The biological activities of these two forms are completely different with the pentavalent form having a low order of toxicity. The trivalent inorganic arsenic is slowly oxidized to the pentavalent form in the upper layers of the earth's crust. Since the organic arsenical herbicides contain the pentavalent form of arsenic, they should be investigated, especially in relation to use as a selective herbicide.

The environmental impact of pentavalent organic arsenicals has been determined by a few investigators. Ehman(7) reported that where DSMA was applied at 5 and 10 lb/acre and crops were replanted within 1 month, residues of arsenic were not found in cotton or crops that are grown in rotation with cotton. Baker, et al.(8), indicate that DSMA could be used for weed control in cotton without significantly increasing the arsenic content of the seed. Cotton treated in prebloom stages showed an arsenic content in cottonseed below 0.2 parts per million (ppm) while cotton treated in postbloom stages increased to 0.45 ppm arsenic in the cottonseed(8). Hamilton and Arle(9), over a 3-year study, showed no reduction in cotton yield using one to three applications per year of MSMA at 2 lb/acre.

There are, however, some reports of arsenic accumulation in crops treated with organic arsenicals. This seems to depend upon rate of application, soil pH, clay content, crop toxicity, and time of application. Singh and Campbell(10) found that both DSMA and MSMA, when applied to bluegrass turf at rates of 4.5 and 4.0 lb/acre, respectively, twice annually for 2 years, persisted in the top 2 inches of soil in amounts great enough to injure oats and soybeans, as shown by bioassay of soil 9 months after the last application. Johnson and Hiltbold(11) showed that, although organic arsenicals did not affect crop yields at rates up to 8.9 kilograms/hectare (kg/ha) (7.9 lb/acre), the arsenic content of harvested material increased and differed with species, rates of application, and methanearsonate materials. Seeds of cotton and soybeans accumulated the highest; sorghum was intermediate; and winter crops of crimson clover, oats, and vetch accumulated the least. They concluded, however, "that erosion, leaching, and crop removal at low levels probably preclude hazardous accumulation of arsenic in most soils treated with normal rates of methanearsonate for weed control."

Von Endt, et al.(12), have shown that soil microbial action will break down 2 to 10 percent of the MSMA in 60 days. Only pentavalent inorganic arsenate and MSMA were detected in thin layer chromatographs after this period of time. Thus, over a period of time MSMA will be converted to the pentavalent inorganic form of arsenic. Dickens and Hiltbold(13) leached DSMA from soil and noted that none was leached below 6 inches. Ehman(7) reported results of leaching experiments with DSMA and cacodylic acid added to the top of soil samples 1 foot in depth. Sixty inches of water extracted 9 percent of the applied arsenicals from a sandy soil and 6 percent from a clay soil. In general, it can be expected that MSMA or the pentavalent inorganic arsenate will remain in the top layer of soil.

Since a small amount of organic arsenicals may get into the irrigation water as a result of ditchbank spraying, the effect of this type herbicide on nontarget

*Numbers in parenthesis designate references at end of report.

organisms should be investigated. McKee and Wolf(14) show that the lethal concentration of sodium arsenate toward minnows is 234 ppm. Bacteria grow in the presence of 10,000 ppm potassium arsenate and algae were not killed at 1,000 ppm(6). Dragonflies, damsel flies, and mayfly nymphs have not been harmed by 14 to 20 ppm arsenate in water(14).

The mandatory U.S. Public Health Service (USPHS) Drinking Water Standard limit for arsenic is 0.05 ppm. Analysis of tapwater from 148 municipalities in the United States, performed by the USPHS, showed arsenic in 26 samples at concentrations ranging from 0.01 to 0.10 ppm. Only three samples contained no detectable arsenic(6). The above levels exceed the 0.002 to 0.005 ppm of arsenic found in sea water.

Most small laterals are normally treated in the field under dewatered conditions. However, it must be realized that it would not only be a substantial economic loss to farmers to dewater the larger main canals while applying a herbicide but also very impractical for project personnel to coordinate and carry out these directives over the entire irrigation season.

Field experiments are being conducted on the Rio Grande Project to determine the levels of MSMA that may enter the irrigation water, soils, and crops during a filled canal herbicide application operation. The objective of this study was to determine the concentration of MSMA that will enter the irrigation water as a result of USBR ditchbank herbicide applications to both dewatered and filled canals. It should be remembered that the soil this water irrigates may contain from 1 to 70 ppm of natural occurring arsenic(6).

SUMMARY

The herbicide, MSMA, was applied to the ditchbanks of irrigation systems on the Rio Grande Project while they were dewatered or full. Samples of treated and untreated water were collected to determine any increase in residues of arsenic in the irrigation water following herbicide application and to furnish analytical data for the preparation of a petition for registration of organic arsenicals for use in weed control along full and dewatered irrigation systems.

Maximum arsenic concentrations found in the first water released through three MSMA-treated ditchbank sections of dewatered laterals were 0.54, 0.12, and 0.29 ppm. Arsenic concentrations dropped to 0.06 ppm and less within 10 minutes in all three laterals.

Maximum arsenic concentration in irrigation water following MSMA application to two full irrigation laterals was 0.16 and 0.17 ppm arsenic. The arsenic concentration in both situations decreased rapidly with respect to time. Another lateral in which the entire water surface along with the two ditchbanks was sprayed showed a maximum arsenic concentration of 0.86 ppm.

Laterals treated while full showed lower maximum arsenic concentration in the water than those treated while dewatered except in one lateral where the entire water surface was inadvertently sprayed. This infers that a greater dilution of the herbicide is obtained when applied to a full system.

Theoretical calculations from the data collected indicate that from 0.002 to 0.04 lb of arsenic per acre per treatment for a 24-hour, 6-inch irrigation could reach the farmland.

MATERIALS AND METHODS

Herbicide Application

The ditchbanks of three laterals were treated with MSMA by a calibrated boom-type spray rig while the laterals were dewatered. Table 1 shows the herbicide application data sheet for these treatments. Within 3 days the water was released into the laterals and samples were taken when the first water reached the end of the MSMA application section.

The ditchbanks of three irrigation systems were treated with MSMA by the same type of spray rig while they were full. Table 2 shows the herbicide application data sheet for these treatments. Samples were taken as soon as the spray rig reached the end of the treated section and turned around to go up the other side. The Franklin Canal and Clint Lateral represent a standard field herbicide application when a canal is full of water. The spray rig applied 5 lb/acre of MSMA to the ditchbanks of these systems while first moving in a downstream direction and then in an upstream direction. The complete lateral surface and both ditchbanks of Lateral T-131 were sprayed concurrently for 2.1 miles while the spray rig moved in a downstream direction. Although this is not the normal method for MSMA application to a ditchbank, it represents the maximum arsenic concentration that could occur in the water of a small lateral under similar conditions.

Table 1

HERBICIDE APPLICATION DATA ON MSMA TREATMENTS MADE ON THREE DEWATERED LATERALS OF THE RIO GRANDE PROJECT IN 1970

Lateral	Flow capacity of lateral (cfs)	Date treated	Date sampled	MSMA rate lb/acre	Treatment description	Place of sample collection	Length treated (mi)
Coffin	15	8-17	8-19	2.4	Sprayed both banks of dry lateral	End of treated section	0.40
Green	12	9-2	9-3	3.2	Sprayed both banks of dry lateral	End of treated section	0.40
Green	12	9-11	9-14	3.2	Sprayed both banks of dry lateral	End of treated section	0.34

Table 2

HERBICIDE APPLICATION DATA ON MSMA TREATMENTS MADE ON THREE FULL IRRIGATION SYSTEMS OF THE RIO GRANDE PROJECT IN 1971

Lateral or canal identity	Flow rate of system (cfs)	Date treated and sampled	Length treated (mi)	MSMA rate (lb/acre)	Treatment description	Place of sample collection	Start of sample collection
T-131 Lateral	11	8-11	2.1	5.0	Sprayed in a downstream direction while applying to both banks and the complete water surface	2.1 miles downstream from beginning	Immediately after spray rig reached the end of the lateral
Franklin Canal	65	8-12	2.25	5.0	Sprayed downstream 2.25 miles on one bank, turned around and sprayed the other bank upstream for 2.25 miles	2.25 miles downstream from beginning of treatment	Immediately after spray rig passed and turned around
Clint Lateral	34	8-26	2.2	5.0	Sprayed downstream 2.2 miles on one bank, turned around and sprayed the other bank upstream for 2.2 miles	2.2 miles downstream from beginning of treatment	Immediately after spray rig passed and turned around

Sample Collection

Water samples were collected in 1-quart (qt) polyethylene bottles to which 10 milliliters (ml) of concentrated HCl was added. On laterals that were dewatered when MSMA was applied, triplicate samples were taken at definite time intervals after the first irrigation water reached the end of the treated sections. On irrigation systems that were full when MSMA was applied, water samples were taken at 5-minute intervals after the spray rig reached the end of the treated section.

The samples were shipped to the Engineering and Research Center, Denver, Colorado, for total arsenic analysis.

Analytical Procedure

A modification of the Sachs, et al.(15), procedure was used to convert the organic MSMA to the inorganic form. This was done by digesting 50 ml of sample with 5 ml of concentrated HNO_3 and 2 ml of concentrated H_2SO_4. The sample was evaporated to dense white fumes and allowed to fume for at least 15 minutes. The silver diethyldithiocarbamate procedure was then used according to APHA(16). A UV-Visible spectrophotometer was used for the colormetric measurements.

RESULTS AND DISCUSSION

Dewatered Irrigation Laterals

Table 3 shows the average concentration of arsenic in ppm found in the water with respect to time as the water passed over the MSMA-treated section of three dewatered irrigation laterals. The Coffin Lateral showed a maximum arsenic concentration of 0.54 ppm immediately after the first water reached the sampling station and decreased to 0.06 ppm arsenic after 10 minutes. In the same manner, the Green Lateral

Table 3

ARSENIC CONCENTRATION FOUND IN FIRST RELEASED WATER SAMPLES AFTER MSMA APPLICATION TO DEWATERED LATERALS

Lateral	Sampling[1] interval (minutes)	Arsenic (ppm)			
		A	B	C	Av
Coffin	Untreated	<0.01	<0.01	<0.01	<0.01
	0	0.59	0.49	0.54	0.54
	5	0.11	0.12	0.12	0.12
	10	0.06	0.07	0.06	0.06
	30	0.04	0.05	0.05	0.05
	60	0.03	0.03	0.03	0.03
	120	0.02	0.01	0.02	0.02
	180	0.01	0.01	0.01	0.01
	240	0.01	0.01	0.01	0.01
Green	Untreated	<0.01	<0.01	–	<0.01
	0	0.05	0.05	0.05	0.05
	5	0.11	0.12	0.13	0.12
	10	0.02	0.02	0.02	0.02
	30	<0.01	<0.01	<0.01	<0.01
	60	<0.01	<0.01	<0.01	<0.01
	120	<0.01	<0.01	<0.01	<0.01
	180	0.01	<0.01	<0.01	<0.01
	240	0.01	<0.01	0.01	0.01
Green	Untreated	<0.01	<0.01	<0.01	<0.01
	0	0.29	0.29	0.29	0.29
	5	0.02	0.02	0.02	0.02
	10	0.01	0.01	0.01	0.01
	30	0.01	0.01	<0.01	0.01
	60	0.01	0.01	0.01	0.01
	120	0.01	0.01	0.01	0.01
	180	0.01	<0.01	<0.01	<0.01
	240	0.01	0.01	0.01	0.01

[1] Minutes after first water reached sampling station.

showed 0.12 ppm arsenic at 5 minutes and decreased to 0.02 ppm arsenic after 10 minutes, while another treated section of the Green Lateral showed 0.29 ppm arsenic initially and decreased to 0.02 ppm arsenic after 5 minutes.

With this type of MSMA application, arsenic levels dropped to and below the mandatory USPHS Drinking Water Standard for arsenic of 0.05 ppm within 10 minutes. This standard is the maximum concentration which can be permitted continuously in potable waters. Thus, applying MSMA to dewatered laterals results in very low levels of arsenic in the first water over the treated sections. Although the water does contain up to 10 times the mandatory USPHS standards in the first 10 minutes, the water in this case is used for irrigation of crops and not for potable supplies.

Full Irrigation Systems

Table 4 shows the concentration of arsenic in ppm found in the water with respect to time after MSMA application to the ditchbanks of three full irrigation systems. The maximum arsenic concentration was 0.16, 0.17, and 0.86 ppm in the Franklin Canal, Clint Lateral, and T-131 Lateral, respectively. Samples were taken every 5 minutes in order to measure as close as possible the maximum arsenic concentration in the irrigation water.

The Franklin Canal is a main delivery canal and is usually full the entire irrigation season. Because of its larger volume of flow, any MSMA that entered the water during herbicide application would be diluted quickly to almost nondetectable levels. After 80 minutes, all arsenic levels remained below the mandatory USPHS Drinking Water Standard of 0.05 ppm.

Clint Lateral remains full most of the irrigation season. The arsenic concentration pattern in this system is very similar to that of the Franklin Canal as arsenic levels decreased to below the mandatory USPHS Drinking Water Standard after 100 minutes.

Lateral T-131 represents the maximum arsenic concentration that could occur in the water of a small lateral since MSMA was applied to the complete water surface for 2.1 miles. Arsenic concentrations varied from 0.12 to 0.86 ppm arsenic for 100 minutes and then declined to values below the mandatory USPHS Drinking Water Standard.

Table 4

ARSENIC CONCENTRATION FOUND IN WATER SAMPLES AFTER MSMA APPLICATION TO FULL IRRIGATION SYSTEMS

Sampling[1] interval (minutes)	Franklin Canal	Arsenic (ppm) Clint Lateral	T-131 Lateral
Untreated	–	–	0.01
Untreated	<0.01	<0.01	0.01
0	0.11	<0.01	0.62
5	0.16	0.04	0.29
10	0.11	0.05	0.86
15	0.03	0.03	0.12
20	0.06	0.09	0.39
25	0.04	0.16	0.50
30	0.07	0.07	0.73
35	0.06	0.11	0.24
40	0.03	0.12	0.19
45	0.07	0.11	0.33
50	0.06	0.08	0.31
55	0.08	0.08	0.35
60	0.06	0.06	0.28
70	0.06	0.17	0.39
80	0.08	0.05	0.48
90	0.04	0.10	0.30
100	0.02	0.07	0.48
110	0.04	0.02	0.04
120	0.02	0.05	0.03
130	0.02	0.01	0.02
140	0.02	0.02	0.01
150	0.02	0.02	0.03
160	0.02	<0.01	0.03
170	0.03	<0.01	0.01
180	0.03	<0.01	0.03
195	0.04	0.01	0.03
210	0.02	0.01	0.07
225	0.02	0.02	0.09
240	0.01	0.02	0.04
255	0.03	0.01	0.01
270	0.02	0.01	0.01
285	0.02	0.01	0.03
300	0.02	0.01	0.04
315	–	<0.01	–

[1] Minutes after spray rig passed end of treated section.

Arsenic Residues on Farmland

It is possible to compute the maximum quantity of arsenic that may be carried to crops from a ditchbank treatment with organic arsenical herbicides using the data on the concentration of arsenic found in the irrigation water, the quantity of water flowing in the system, and an average figure for inches of irrigation water applied for a given length of time. The applied arsenical is in the water for a relatively short period of time and may be distributed to a small number of acres at any one treatment. However, in accounting for the distribution of the arsenic in the water for a number of treatments, it is reasonable to assume that the material will be distributed over the entire acreage being irrigated. Hence for each cubic feet per second of flow for 24 hours you distribute 2 acre-feet of water or on applying 6 inches per acre you will cover an area of 4 acres. A 6-inch irrigation applied over a 24-hour period is used in these computations. The average concentration of arsenic in the irrigation water was computed and then converted to total pounds on the basis of the quantity of water flowing in the system for the time period.

The maximum quantity of arsenic that could get to the cropland per treatment on the basis of the data presented and the method used for computing the predicted quantities is shown in Table 5. These calculations indicate that levels of 0.002 to 0.04 lb of arsenic per acre per treatment for a 24-hour, 6-inch irrigation could reach the farmland. The organic arsenicals are applied up to four times per season. These figures can be compared to natural background arsenic values of up to 15 lb/acre which may occur in the top 6 inches of soil.

Knowing that arsenic is readily absorbed in soil, it is not likely that much of the arsenic found in the water actually reaches the crop plant in a form available for plant uptake since the water is transported through earthen ditches and carries a high silt load.

Organic Arsenical Analysis

The organic form of arsenic must be converted to the inorganic form before the generation of arsine gas. Several digestion procedures have been used to determine the inorganic arsenic content of soils(17) and feeds(18). Sachs, et al.(15), used a combination of nitric and sulfuric acid to convert MSMA to the inorganic form in plant tissue. To determine the percent recovery of the digestion step, a modification of the Sachs procedure was to add 5 ml of concentrated nitric, and 2 ml of concentrated sulfuric to 50 ml of irrigation water containing 4.0 micrograms (μg) of arsenic as MSMA. Table 6 shows the percent recovery of arsenic from water containing MSMA using hot nitric-sulfuric acid digestion. Only 32 percent arsenic was recovered from water containing MSMA using no heating.

Table 5

QUANTITY OF ARSENIC COMPUTED FROM LEVELS OF ORGANIC ARSENICALS FOUND IN IRRIGATION WATER THAT MAY BE DISTRIBUTED TO FARMLAND FROM DITCHBANK APPLICATIONS OF ORGANIC ARSENICALS

Condition on treatment	Irrigation system identity	Flow (cfs)	Average arsenic in water (ppm)	Computed pounds of arsenic applied/ acre/treatment for a 24-hour, 6-inch irrigation
Dewatered	Coffin Green Green	13 average for the 3	0.054 for 30 minutes	0.002
Watered	T-131	11	0.396 for 100 minutes	0.04
	Franklin	65	0.066 for 100 minutes	0.006
	Clint	34	0.087 for 100 minutes	0.01

Table 6

PERCENT RECOVERY OF ARSENIC FROM MSMA IN WATER USING HOT NITRIC-SULFURIC ACID DIGESTION

Heating time after appearance of dense white fumes (minutes)	Percent recovery (arsenic)
0	41
0	56
0	57
15	98
15	98
15	97
30	100
30	100
30	97
60	91
60	96
60	97
180	100
180	98
180	96
Dryness	7

For maximum recovery, the sample must be heated at least 15 minutes after the appearance of dense white fumes. If the heating is carried to dryness, the arsenic will volatilize and be lost. The silver diethyldithiocarbamate (SDDC)(18) procedure was used for arsenic analysis after digestion. Triplicate samples were analyzed at each heating time.

The irrigation water on the Rio Grande Project contains a high sediment load. Since Dickens(13) and Ehman(7) reported that MSMA remains in the top layer of soil, the absorption of MSMA by the suspended sediment in the irrigation water during sample storage was investigated. Table 7 shows the effect of sample treatment on MSMA concentration in Rio Grande Project irrigation water during storage. Tests on irrigation water consisted of samples of nonfiltered, filtered, and nonfiltered containing 10 ml of concentrated HCl. All samples were spiked with 0.1 μg/ml of arsenic as MSMA. Nonfiltered samples showed a loss of 28 percent MSMA in 36 days. Filtered samples showed less than 7 percent loss in 36 days, while acidified samples showed 6 percent loss in 36 days. Therefore, all samples are now acidified on collection in the field with 10 ml of concentrated HCl to maintain a uniform concentration of arsenic in the water sample.

Table 7

EFFECT OF SAMPLE TREATMENT ON MSMA CONCENTRATION IN RIO GRANDE PROJECT IRRIGATION WATER DURING STORAGE

Lateral	Treatment	Storage time (days)	Percent loss MSMA
Salem	Nonfiltered	2	4
		6	6
		36	27
Ricon	Nonfiltered	2	10
		13	12
		36	28
Salem	Filtered	2	4
		6	5
		13	3
		36	1
Ricon	Filtered	2	6
		6	1
		13	4
		36	7
Rodnen	Nonfiltered and 10 ml HCl (acidified)	2	4
		6	0
		13	0
		36	6

REFERENCES

1. Rea, H. E., "Organic Arsenicals for Controlling Johnsongrass in Cotton Fields," Proceedings, Southern Weed Conference, 1964

2. Stevens, G. D., "Progress in Weed Control Research With Organic Arsenical Herbicides," Proceedings, Southern Weed Conference, 1965

3. Arle, H. F. and Hamilton, R. C., "Directed Application of Low-Rates of Herbicides on Cotton," Research Progress Report, Western Weed Control Conference, 1966

4. McWhorter, C. G., "Toxicity of DSMA on Johnson Grass," *Weeds,* Vol. 14, pp 191-194, 1966

5. Kirby, J. W. and Summers, A. D., "Weed Control in Arid Southwest," Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, Vol. 97, No. IR4, December 1971

6. Schroeder, H. A. and Balassa, J. J., "Abnormal Trace Metals in Man: Arsenic," *Journal of Chronic Diseases,* Vol. 19, pp 85-106, 1966

7. Ehman, P. J., 1965, Effect of Arsenical Buildup in the Soil on Subsequent Growth and Residue Content of Crops, Proceedings, Southern Weed Conference 18: 685-687

8. Baker, R. S., Arle, H. F., Miller, J. H., and Halstun, J. T., "Effects of Organic Arsenical Herbicides on Cotton Response and Chemical Residues," *Weed Science,* Vol. 17, pp 37-40, 1968

9. Hamilton, K. C., and Arle, H. F., "Directed Applications of Herbicides in Irrigated Cotton," *Weed Science,* Vol. 18, pp 85-88, 1970

10. Singh, R.K.N. and Campbell, R. W., "Herbicide on Bluegrass," *Weeds,* Vol. 13, pp 170-171, 1965

11. Johnson, L. R. and Hiltbold, A. E., "Arsenic Content of Soil and Crops Following Use of Methanearsonate Herbicides," Soil Sci. Soc. Amer. Proc., Vol. 33, pp 279-282, 1969

12. Von Endt, D. W., Kearney, P. C., and Kaufman, D. D., "Degradation of Monosodium Methanearsonic Acid by Soil Microorganisms," *Agric. and Food Chemical,* Vol. 16, No. 1, January-February 1968

13. Dickens, R. and Hiltbold, A. E., "Movement and Persistence of Methanearsonates in Soil," *Weeds,* Vol. 15, No. 4, pp 299-304, 1967

14. McKee, J. E. and Wolf, H. W., "State of California: Water Quality Criteria," Second Edition, State Water Pollution Control Board, Publication No. 3-A, Sacramento, 1963

15. Sachs, R. M., Michael, J. L., Anastasia, F. B., and Wells, W. A., "Determination of Arsenic Herbicide Residues in Plant Tissues," *Weed Science,* Vol. 19, June 4, pp 412-416, 1971

16. Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965, APHA, AWWA, WPCF, p 56

17. Woolson, E. A., Axley, H., and Kearney, P. C., "Comparison of a Colorimetric and a Coulometric Method for the Determination of Arsenic in Soil Digests," Soil Science, Vol. III, No. 3, pp 158-162, 1971

18. Morrison, J. I., "The Determination of Total Arsenic in Medicated Feeds, Using Silver Diethyldithiocarbamate," Journal of the AOAC, Vol. 44, No. 4, pp 740-741, 1961

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Bureau of Reclamation

CONVERSION FACTORS–BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg, that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
Inches	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
Feet	0.3048 (exactly)*	Meters
Feet	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
Miles	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	*929.03	Square centimeters
Square feet	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	*0.40469	Hectares
Acres	*4,046.9	Square meters
Acres	*0.0040469	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
Fluid ounces (U.S.)	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
Liquid pints (U.S.)	0.473166	Liters
Quarts (U.S.)	*946.358	Cubic centimeters
Quarts (U.S.)	*0.946331	Liters
Gallons (U.S.)	*3,785.43	Cubic centimeters
Gallons (U.S.)	3.78543	Cubic decimeters
Gallons (U.S.)	3.78533	Liters
Gallons (U.S.)	*0.00378543	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
Gallons (U.K.)	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	*764.55	Liters
Acre-feet	*1,233.5	Cubic meters
Acre-feet	*1,233,500	Liters

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
Short tons (2,000 lb)	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
Pounds per square inch	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
Pounds per square foot	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
Pounds per cubic foot	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
Inch-pounds	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
Foot-pounds	1.35582×10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
Feet per second	0.3048 (exactly)*	Meters per second
Feet per year	$*0.965873 \times 10^{-6}$	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
Miles per hour	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	*0.3048	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	*0.028317	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	*0.453592	Kilograms
Pounds	*4.4482	Newtons
Pounds	$*4.4482 \times 10^5$	Dynes

Multiply	By	To obtain
WORK AND ENERGY*		
British thermal units (Btu)	*0.252	Kilogram calories
British thermal units (Btu)	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	*1.35582	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 degree F (k, thermal conductivity)	1.442	Milliwatts/cm degree C
Btu in./hr ft^2 degree F (k, thermal conductivity)	0.1240	Kg cal/hr m degree C
Btu ft/hr ft^2 degree F	*1.4880	Kg cal m/hr m^2 degree C
Btu/hr ft^2 degree F (C, thermal conductance)	0.568	Milliwatts/cm^2 degree C
Btu/hr ft^2 degree F (C, thermal conductance)	4.882	Kg cal/hr m^2 degree C
Degree F hr ft^2/Btu (R, thermal resistance)	1.761	Degree C cm^2/milliwatt
Btu/lb degree F (c, heat capacity)	4.1868	J/g degree C
Btu/lb degree F	*1.000	Cal/gram degree C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
Ft^2/hr (thermal diffusivity)	*0.09290	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor) transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	*304.8	Liters per square meter per day
Pound-seconds per square foot (viscosity)	*4.8824	Kilogram second per square meter
Square feet per second (viscosity)	*0.092903	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	*35.3147	Millicuries per cubic meter
Milliamps per square foot	*10.7639	Milliamps per square meter
Gallons per square yard	*4.527219	Liters per square meter
Pounds per inch	*0.17858	Kilograms per centimeter

GPO 845-418

ABSTRACT

Monosodium methanearsonate (MSMA) was applied to the ditchbanks of full and dewatered irrigation systems on the Rio Grande Project to control ditchbank weeds and to determine the MSMA residues in irrigation water. Information obtained will provide support for the registration of organic arsenicals used for weed control along full and/or dewatered ditchbanks. Water samples were analyzed for total arsenic content after sulfuric-nitric acid digestion by the silver diethyldithiocarbamate method. Maximum arsenic concentrations found in the first water released through dewatered laterals were 0.54, 0.12, and 0.29 ppm, dropping below the mandatory U.S. Public Health Service Drinking Water Standards for arsenic within 10 minutes. Maximum arsenic concentrations in full systems following MSMA herbicide application to ditchbanks were 0.16, 0.17, and 0.86 ppm, but dropped rapidly after a period of time. Test results show that low levels of arsenic occur in irrigation water for short periods of time following ditchbank applications of MSMA. Theoretical calculations indicate that from 0.002 to 0.04 lb of arsenic per acre per treatment could reach the farmland during a 24-hour period using 6 inches of irrigation water.

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DESCRIPTORS–/ bibliographies/ *herbicides/ *weed control/ dewatering/ irrigation canals/ *water analysis/ irrigation water/ *arsenicals (pesticides)/ gas chromatography/ *pesticide residues/ potable water/ field investigations/ field crops/ test results/ organic pesticides
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